## GROUND-WATER QUALITY

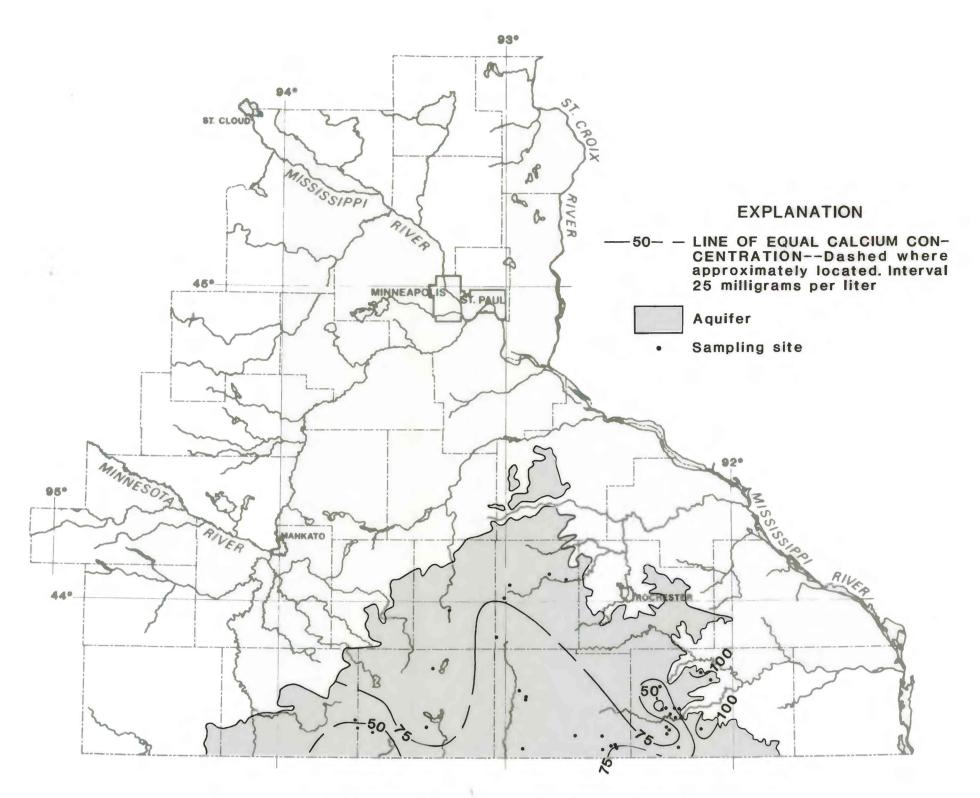
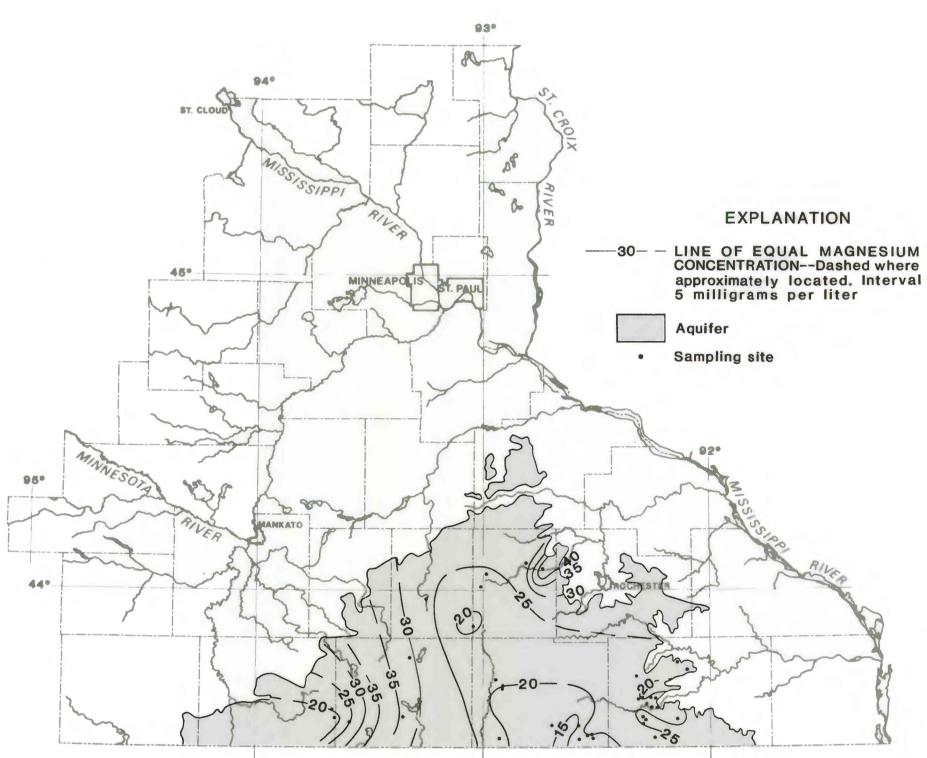


Figure 9.--Calcium concentration



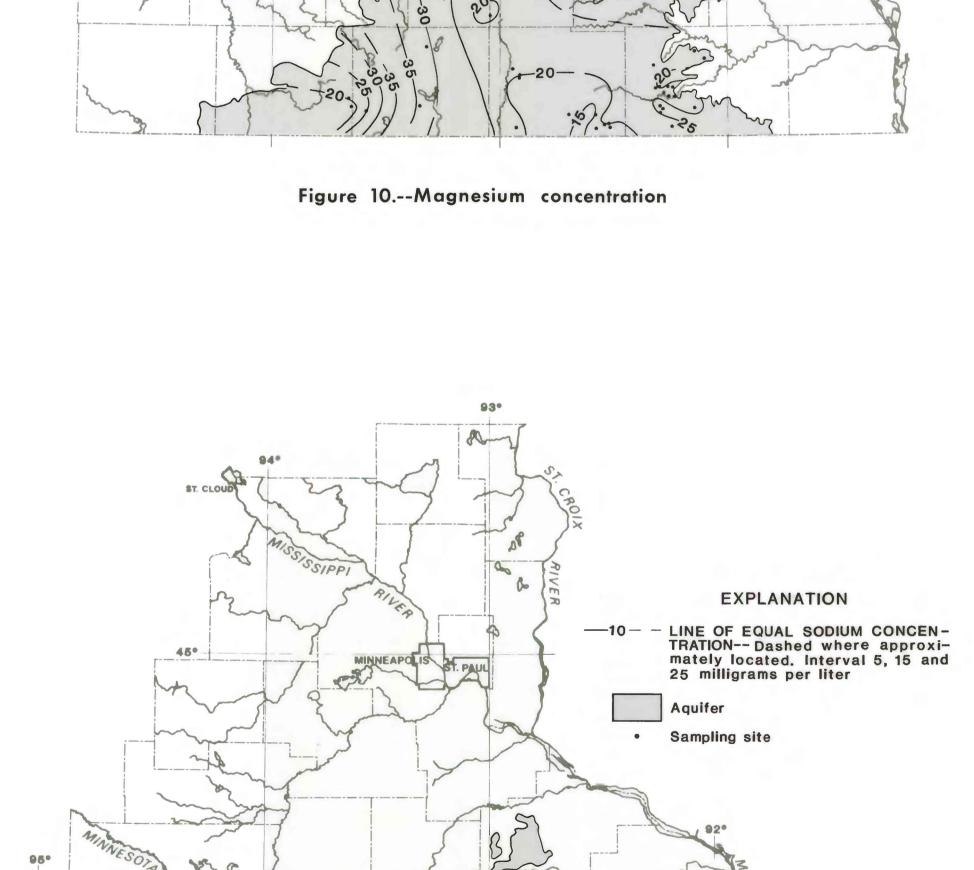


Figure 11.--Sodium concentration

#### WATER QUALITY

The quality of water in the Upper Carbonate aquifer is suitable for most uses; however, the water is potentially vulnerable to contamination in the eastern part of the study area where karst features are common. The mean, median, and range of selected chemical-constituent concentrations and properties of water from the aquifer are shown in table 2. Values used in the preparation of table 2 and the dissolvedsolids and ion-concentration maps (figs. 8-14) are based on data from the U.S. Geological Survey Water Data Storage and Retrieval System (WATSTORE) and from the U.S. Environmental Protection Agency Storage and Retrieval System (STORET). Most results of chemical analyses were obtained in the period 1960-80.

# Table 2.—Summary of representative water-quality analyses of water from the aquifer

Values are given in milligrams per liter except as indicated.

µmho/cm, micromhos per centimeter; µg/L, microgram per liter

Constituent or property	maximum or range for pub- lic supply1/	Number of analyses	Mean	Median	Minimum	Maximu
Specific conductivity,						
(µmho/em at 25°C)		45	589	560	295	1050
рН	5.0-9.0	49		7.4	7.0	8.
Temperature, water						
(°C)		41	9.2	9.3	6.4	11.
Hardness as CaCO3						
(Mg, Ca)		52	290	280	130	420
Noncarbonate hardness Calcium, dissolved		44	28	18	<1	110
(Ca)		50	75	74	27	110
Magnesium, dissolved		30	15	1.4	21	110
(Mg)		50	24	22	11	43
Sodium, dissolved (Na)		50	19	6.0		
Sodium percentage		50		4	2.0	143
Potassium, dissolved		50	10	4	2	61
(K)	2000	52	2	2	6	16
Bicarbonate (HCO3)		41	341	329	225	560
Carbonate (CO <sub>3</sub> )		15007	-	-		
Sulfate, dissolved		14	<1	<1	<1	0
(SO <sub>4</sub> )	250	50	24	20	<1	70
Chloride, dissolved	250	EO	7 1	2 2	2	27
(C1)	250	50	7.1	2.3	•3	37
Fluoride, dissolved		52	2	2	7.1	
(F) Silica, dissolved		32	.2	.2	- 1	
		48	10	4.0		11.0
(SiO <sub>2</sub> ) Dissolved solids (res-		40	19	18	5.1	48
idue on evaporation						
at 180°C)	. 500	41	252	226	100	560
Nitrate, dissolved	. 500	41	353	336	190	560
as N	. 10	11	.58	lin	0.0	2
Boron, dissolved (B),	. 10	- ''	.50	.43	.02	2.
		46	180	60	<10	700
Mg/L Phosphate, dissolved		40	100	00	(10	790
		10	02	/ 04		
(PO <sub>4</sub> ) Phosphorus, dissolved		10	.03	<.01	<.01	
(P)		33	.09	.08	<.01	
Iron, dissolved as Fe,		33	.09	.00	1.01	
μg/L	. 300	25	1500	1200	20	5300
Manganese, total as	. 300	23	1500	1200	20	5300
	. 50	25	40	20	<1	120
Mn, µg/L	. 50	23	40	20	(1	130

## Dissolved Solids

Dissolved-solids concentration, a measure of the dissolved substances in water, is a common indicator of the suitability of water for various uses. Water with less than 500 mg/L dissolved solids generally is satisfactory for domestic and industrial uses. The recommended maximum for dissolved solids proposed by the U.S. Environmental Protection Agency (1977) for drinking water is 500 mg/L.

Dissolved-solids concentrations generally are lower in the eastern part of the study area. Much of the recharge in this area is from precipitation with a low mineral content. This water infiltrates the aquifer through thin drift in predominantly karst terrain (fig. 8). The high values of about 500 mg/L are in the southwest and northeast. Leakage of mineralized water from thick drift and, possibly Cretaceous deposits, probably causes the high values in these areas.

### Water Types and Major Ions

Ground water is commonly classified on the basis of relative concentrations in milliequivalents of major cations and anions. Water from the Upper Carbonate aquifer is predominantly of the calcium magnesium bicarbonate type, as shown by the water-type patterns in figure 8. This type of water is common in recharge areas and throughout the upper part of the ground-water system in Minnesota (Winter, 1974).

The concentrations of the major ions in the aquifer do not vary uniformly (figs. 10-14). Some of the ions, specifically sodium, bicarbonate, and sulfate, increase in concentration toward the southwestern part of the study area. Inflow of mineralized water from thick drift and possibly Cretaceous rocks probably causes the increases. Calcium concentration is higher to the north and east, and chloride concentrations are generally low throughout the aquifer, except for some locally high values in the eastern and southeastern parts of the study

#### Water-Quality Problems

The potential for contamination of the Upper Carbonate aquifer increases in the eastern part of the study area where the drift is less than 50 feet thick and karst features are common. The Minnesota Department of Health considers contamination of the aquifer in karst areas to be one of the major ground-water-quality problems in the State (Minnesota Department of Health, 1976). Sinkholes and disappearing streams in the karst areas provide direct passageways for entry of contaminants into the aquifer. Nitrates and pathogenic bacteria from livestock feedlots and septic tanks, and pesticides from agri-chemicals are potential contaminants.

# CONVERSION FACTORS

Multiply inch-pound unit	Ву	To obtain SI (metric) unit		
foot (ft)	0.3048	meter (m)		
gallon (gal)	3.785	liter (L)		
gallon per minute (gal/min)	0.06309	liter per second (L/s)		
square mile (mi <sup>2</sup> )	2.590	square kilometer (km²)		
micromho per centimeter (µmho/cm at 25°C)	1.000	microsiemens per centimeter (us/cm at 25°C)		

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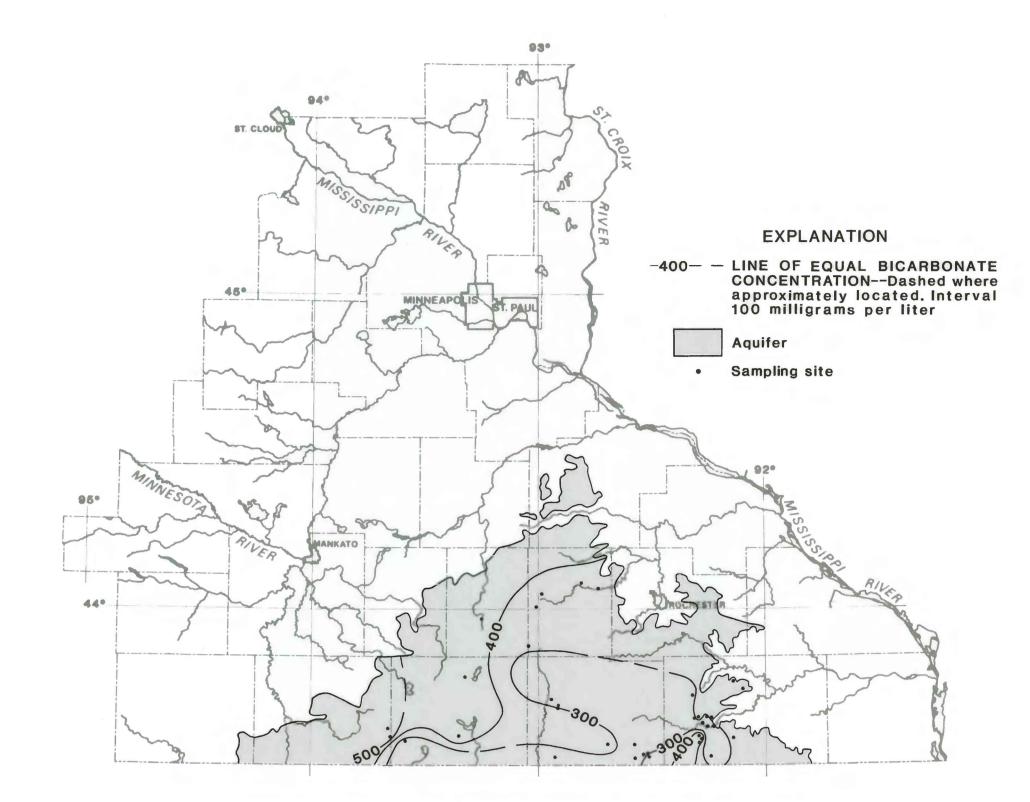


Figure 12.--Bicarbonate concentration

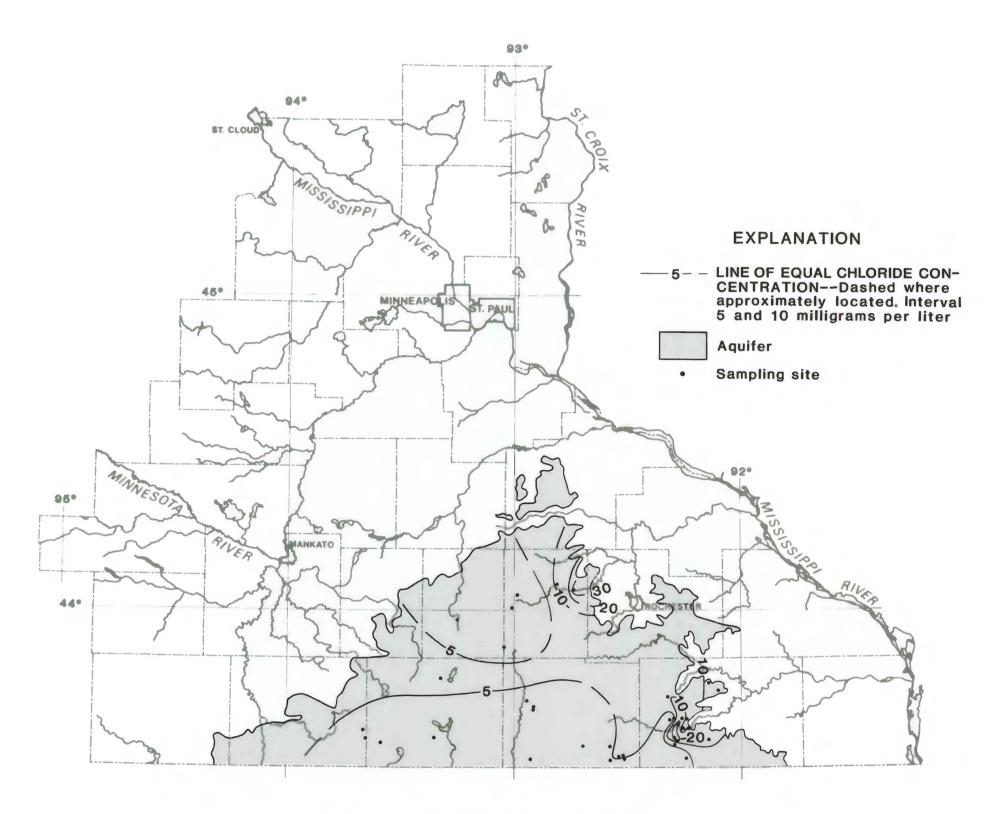


Figure 13.--Chloride concentration

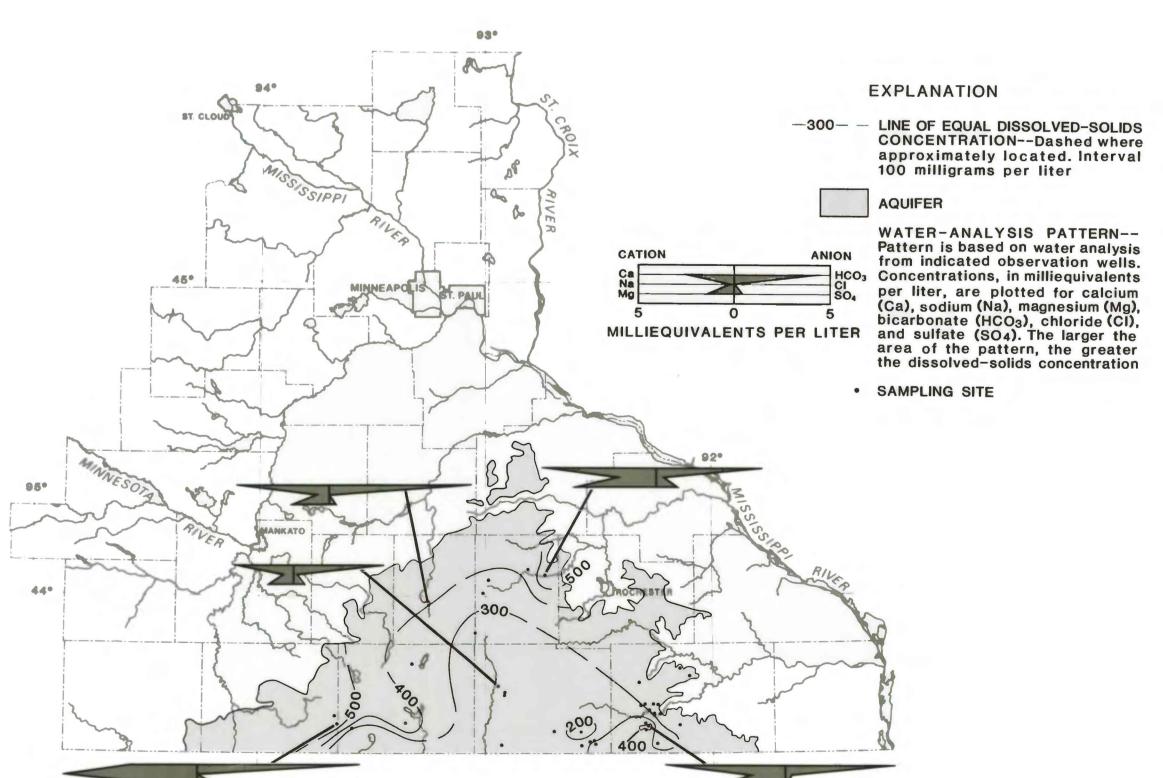


Figure 8.--Dissolved—solids concentration and water—type patterns

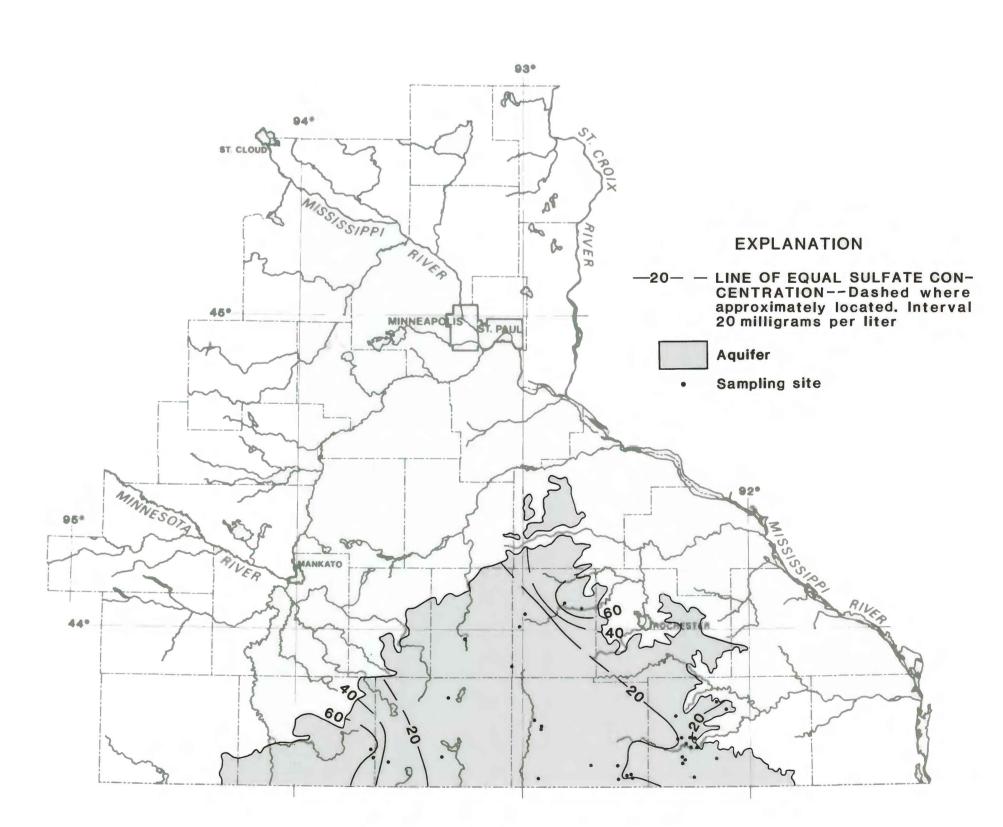


Figure 14.--Sulfate concentration

HYDROGEOLOGIC AND WATER-QUALITY CHARACTERISTICS OF THE UPPER CARBONATE AQUIFER IN MINNESOTA

BY
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